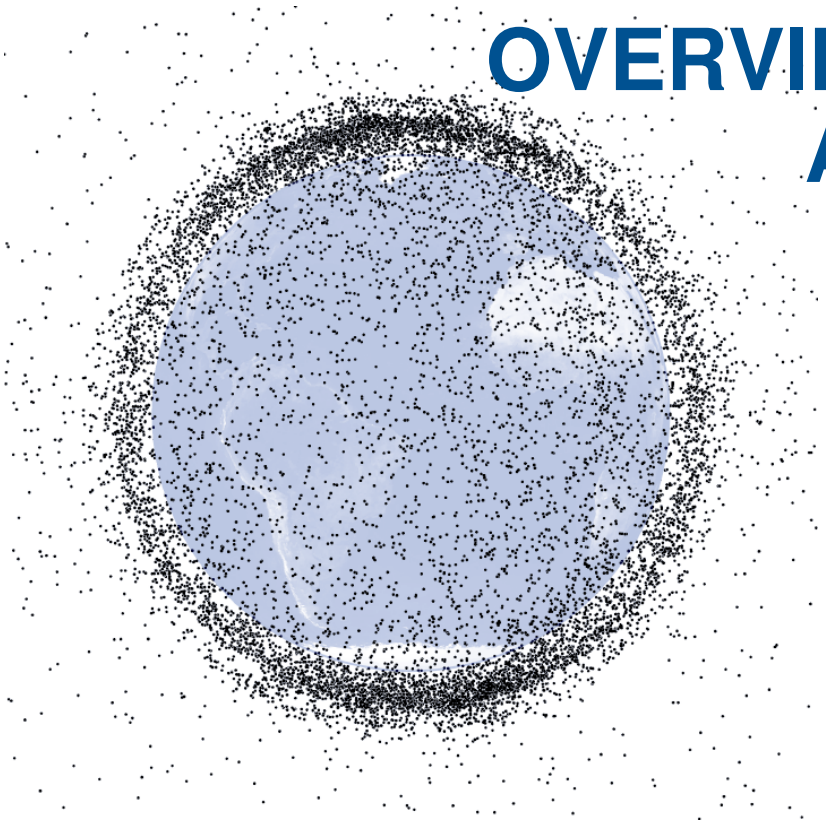
OVERVIEW ON SPACE DEBRIS ACTIVITIES IN FRANCE



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CONTENT

- *Regulatory framework*
- *End of life operations*
- *Collision risk monitoring*
- *Studies (Active Space Debris Removal)*

REGULATORY FRAMEWORK

- Space Operations Act voted by the French Parliament in June 2008
- Law entered into force on December 10, 2010
- Objectives: protection of people, property, public health and environment (including on orbit)
- Applicable to:
  - Operators carrying out operations from French territory
  - French operators carrying out operations anywhere in the world
- Operators shall demonstrate compliance w.r.t. Technical Regulations
- Authorizations are granted by the Ministry of Research after analysis of technical aspects by CNES

REGULATORY FRAMEWORK

- Technical provisions mandatory for space operators and applicable to any space system:
  - Specific rules for Launchers
  - Specific rules for Satellites
- Main common principles:
  - Mitigation of debris:
    - » For launchers : for launch of a single space object, a single launcher element (upper stage) may be placed in orbit; for launch of several space objects, a maximum of two launcher elements (upper stage and the adapter structure) may be placed in orbit
    - » For satellites: no debris produced during nominal operations
  - Probability of occurrence of accidental break-up must be less than 10^{-3} until the end-of-life of the space object

REGULATORY FRAMEWORK

- Following the disposal phase:
  - all the on-board energy reserves shall be permanently depleted or placed in a state such that depletion of the on-board energy reserves is inevitable, or in a state such that they entail no risk of generating debris;
  - all on-board energy production means shall be permanently deactivated
- Obligation to de-orbit the components of any space system (through controlled re-entry or through the “25-years” rule) or to put them on a graveyard orbit
- Interim provisions : some of the rules of the technical regulations are not fully applicable to existing space systems

REGULATORY FRAMEWORK

- Conformity verification office has been set up
- Technical compliance is checked by CNES before launch or critical operations
- Methods and tools are proposed to support the implementation of the Technical Regulations:
  - Fragmentation modeling during reentry: DEBRISK
  - Estimation of ground risk in case of reentry: ELECTRA
  - Determination of compliance with the 25-year rule: STELA
  - Long term stability of the GEO graveyard orbit
  - Collision risk during launch phase: ARCL

END OF LIFE OPERATIONS : DEMETER satellite

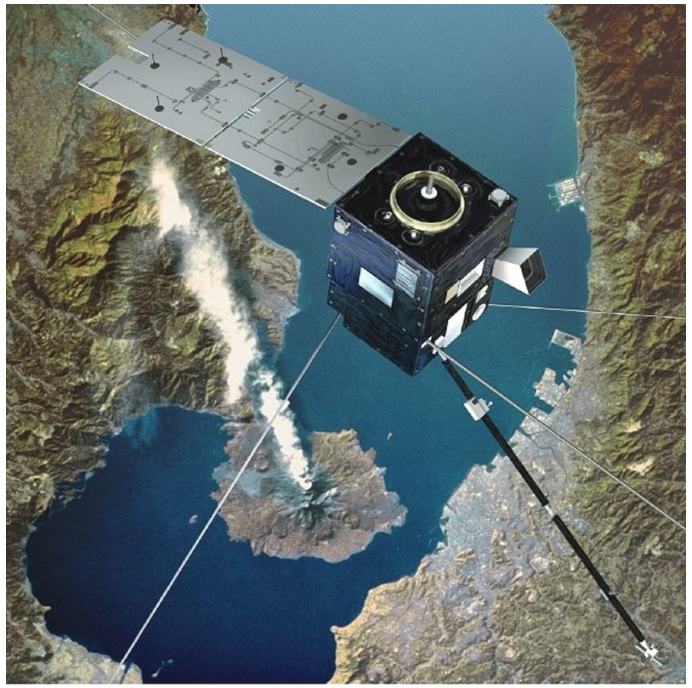
- Detection of Electro Magnetic Emissions Transmitted from Earthquake Regions

- Main characteristics:
  - Size: about 1 m x 1 m x 1 m
  - Mass 120 kg
  - Power 190 W at Beginning of Life

- Launched in June 2004

- Initial orbit 700 km SSO, local hour 22h

- Orbit lowered in 2006 following solar panel anomaly



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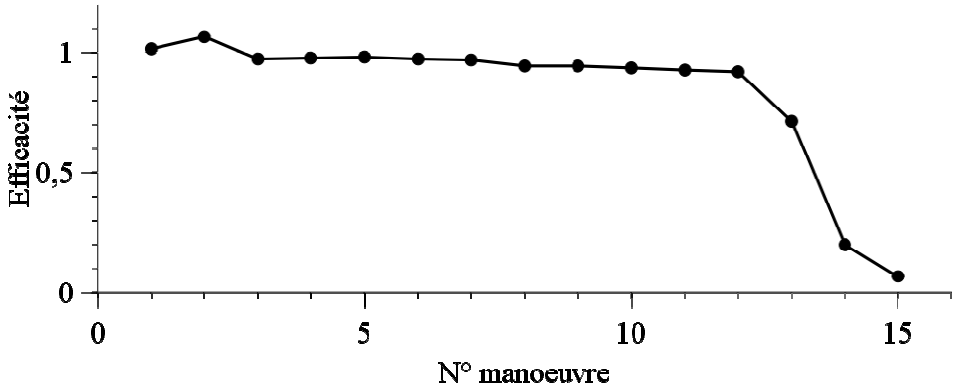
END OF LIFE OPERATIONS : DEMETER satellite

- Disposal operations:
  - 15 burns (January 4 - February 8, 2011)
  - Fuel exhausted during 13th burn
  - Burn #14 and #15 with lower pressure
- Final orbit 650 km x 650 km
- Passivation:
  - Batteries discharged
  - Solar panel power shunted
  - S band transmitters off
- Atmospheric re-entry expected in less than 25 years



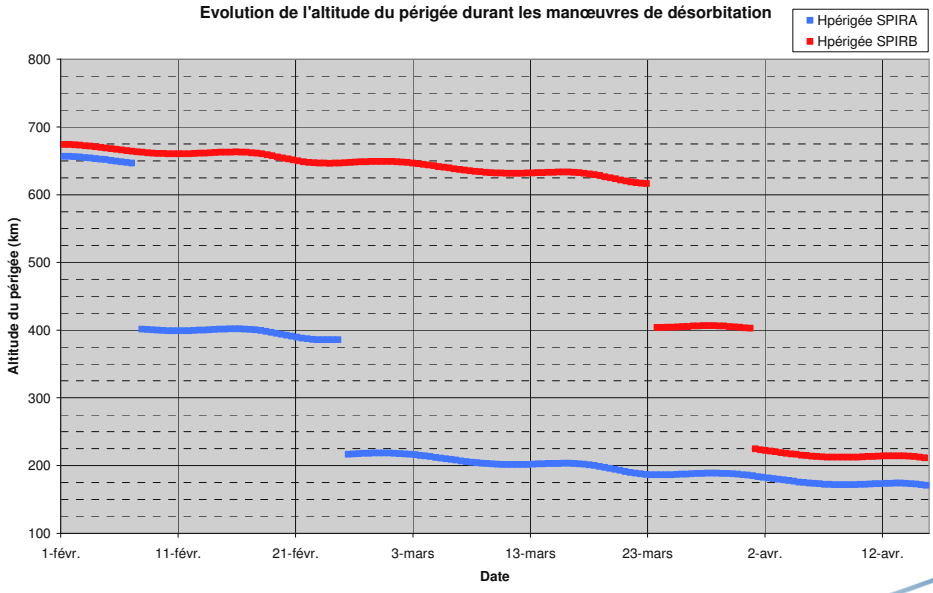
END OF LIFE OPERATIONS : SPIRALE satellites

Spirale : *Système Préparatoire Infra-Rouge pour l'ALErte*

- 2 micro satellites launched with Ariane 5 on 12 February 2009
- Geostationary Transfer Orbit 600 km x 35720 km
- Controlled by ASTRIUM Toulouse
- End of life operations in February and March 2011

END OF LIFE OPERATIONS : SPIRALE satellites

- Perigee altitude lowered to 200 km
- 2 maneuvers per satellite
- No collision risk with GEO satellites and with ISS due to orientation of the orbital plane
- Remaining orbital lifetime estimation very sensitive to:
  - S/m ratio
  - Sun and Moon attraction
- Simulations show compliance with the 25-year rule



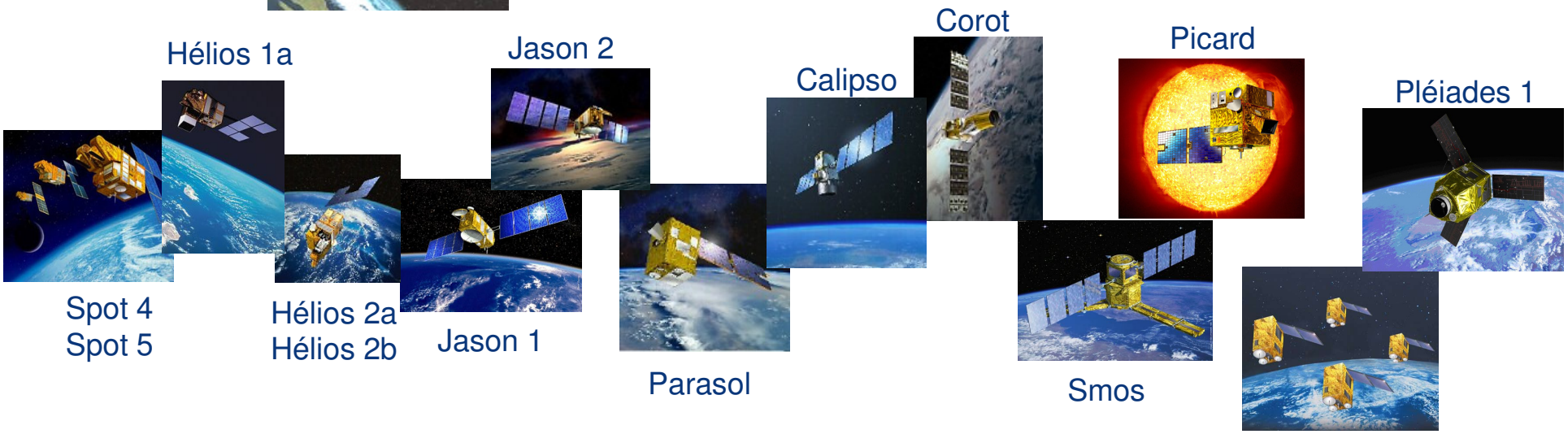
END OF LIFE OPERATIONS : EUTELSAT W75

- EUTELSAT W75 (ex HB3) launched on November 2, 1997
- Thrusters anomaly => satellite disposal decided by Eutelsat
- Nominal strategy: due to reduced efficiency the perigee would have been raised by less than 100 km
- Alternative strategy: reorbiting below GEO arc

- Passivation:
  - Fuel exhausted
  - Batteries configured to permanently discharge.
  - Switch-off on July 5, 2011

- Final Orbit:
  - Apogee radius: ~41655 km (~508 km below GEO)
  - Perigee radius: ~41448 km (~716 km below GEO)

COLLISION RISK MONITORING



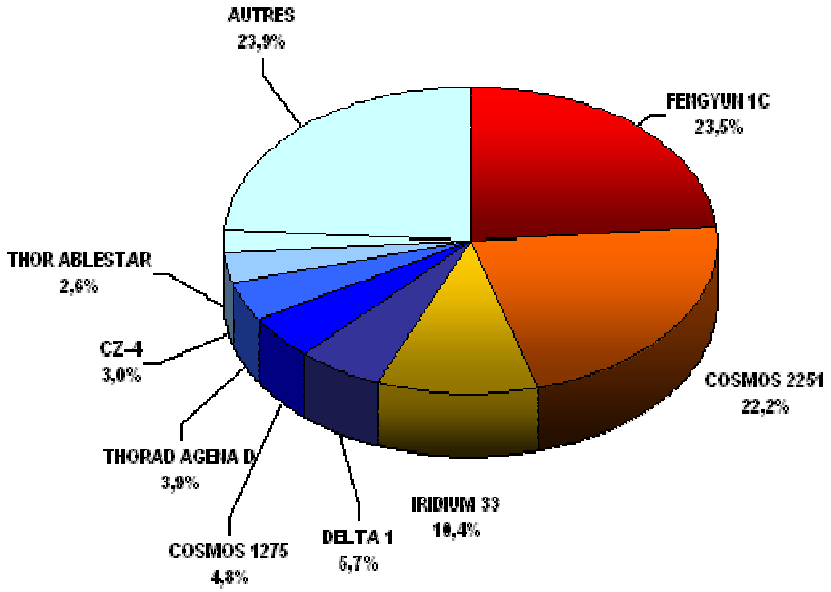
=> 17 LEO satellites and 1 GEO satellite controlled by CNES

Permanent collision risk monitoring and avoidance maneuvers when necessary:

- Use of Conjunction Summary Messages received from US Joint Space Operations Center (JSpOC)
- Use of the Graves (French radar system) catalogue and measurements

COLLISION RISK MONITORING

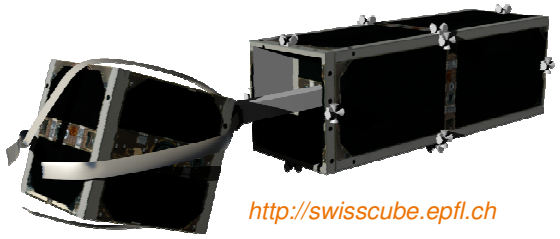
2011 synthesis:



- 122 risks identified by the automated process (probability of collision > 10^{-4})
- 89 risk alerts received from US JSpOC
- 15 requests for radar measurements or support to JSpOC (probability of collision > 10^{-3})
- 5 avoidance maneuvers

ACTIVE SPACE DEBRIS REMOVAL

- Increasing risk to operational satellite
- Mitigation measures will not be sufficient
- Active Space Debris Removal will be necessary
- Complex issue: technical, economical and legal aspects



http://swisscube.epfl.ch

ACTIVE SPACE DEBRIS REMOVAL

- Several on-going studies at CNES, ASTRIUM, THALES ALENIA SPACE and BERTIN
- Objective to identify technical difficulties and critical technologies:
  - *Rendez-vous* with non cooperative target
  - Capture of a tumbling object
  - De-orbiting solutions: propulsion, tethers, inflatable devices,…
- Development of a space debris population model to analyze:
  - Future evolution
  - Influence of mitigation options
  - Risk level evaluation
  - Target selection

- 2nd European workshop on Active Space Debris Removal: 18-19 June 2012